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Climate Change Policy

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THE GLOBAL WARMING PROBLEM

• Climate is actually changing….
  – Temperature increases
  – Sea level rises
  – Precipitation patterns change and extreme events (hurricanes, floods, droughts,...) are more frequent
  – Ice cover is smaller and smaller...
Average temperature: 1880 - 2000

CLIMATE IS CHANGING ...
Sea level rise: 1880 - 2000

CLIMATE IS CHANGING ...
CLIMATE IS CHANGING...

Global costs of extreme weather events (inflation-adjusted)

- Annual losses, in thousand million U.S. dollars
- Total economic losses
- Insured losses
- Number of events
- Decadal average

SYR - FIGURE 2.7

IPCC
INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE
CLIMATE CHANGE IS A COMPLEX PROBLEM

Two basic questions:

• Do we actually need a climate policy?

• If yes, how should it be designed?
DO WE ACTUALLY NEED A CLIMATE POLICY?

Usual questions:

• Does climate change exists?
• If yes, is there a human influence on climate change?
• If yes, are there market failures?
• If yes, do we need a global climate regime?
Climate policy has two components:

– Mitigation
– Adaptation

• Above questions refer to mitigation. Biased approach.

• What about adaptation? Adaptation can be necessary even in the absence of human influence on climate.
• Different mitigation options
• Incentives for global and sub-global coordination
• New policy architectures
• Modelling issues for mitigation policy …

• … however, main point will be the necessity to improve modelling of adaptation strategies and of their economic implications.
IS THERE A HUMAN INFLUENCE ON CLIMATE?

• Climate has always been changing

• Therefore, uncertainty is not about whether there is climate change, but about how much climate change is induced by human activities … i.e. whether there is a human influence on the speed of climate change.
HUMAN INFLUENCE ON CLIMATE CHANGE?

![Graph showing temperature change over time with labels for Holocene maximum and Little ice age.](image)
Comparison between model and observations of the temperature rise since 1860

(a) Natural forcing only

(b) Anthropogenic forcing only

(c) Natural + Anthropogenic forcing

Model results
Observations
Human influence on climate implies that future changes of climatic variables are likely to be much larger and faster than those observed in the past...
Temperature change (1760 - 2100)

Scenarios:
- A1
- A1B
- A1FI
- A2
- B1
- B2
- IS92a high (TAR method)
- IS92a (TAR method)
- IS92a low (TAR method)

Model ensemble all SRES envelope

Bars show the range in 2100 produced by several models
Global average sea level rise (1990 - 2100) for the six SRES Scenarios

Sea level rise (metres)

Range in 2100

Bars show the range in 2100 produced by several models

Scenarios
- A1
- A1T
- A1FI
- A2
- B1
- B2

All SRES envelope including land-ice uncertainty

Several models all SRES envelope

Model average all SRES envelope

2000 2020 2040 2060 2080 2100
THEREFORE:

• Climate change is inevitable.

• Future changes may be larger, but not much larger than what they would be without human influences.

• A risk-averse strategy requires the adoption of mitigation measures.

• Whatever the conclusion on the human influence issue, adaptation investments are/will be necessary (as in past centuries)
  - Romans’ *termae* (spa) ....
HOW SHOULD CLIMATE POLICY BE DESIGNED?

MITIGATION

• Why is it difficult to reach an agreement on GHG emission reductions?

• Climate change control is a global public good. “Tragedy of the commons”?

• Economic asymmetries, equity concerns?
POLICY ISSUE 1: NO COOPERATION OR GLOBAL COOPERATION?

- **Theory**: No cooperation or full cooperation at the equilibrium. International environmental agreements as a Prisoners’ dilemma.

- **Facts**: Many international agreements are partial and in particular the present climate agreement (Kyoto Protocol) is a partial agreement.

- **New Theory**: Coordination game and not Prisoners’ dilemma. Partial agreements at the equilibrium

- **Prediction**: Either a few number of signatories or empty agreement
Gains from cooperation and from free-riding when a stable coalition exists

\[ c^* \]

\[ n \]

\[ c \]

=> Coordination game
Coalition Theory (2)

Gains from cooperation and from free-riding when no stable coalition exists => Prisoners’ dilemma
Gains from cooperation and from free-riding in the presence of leakage $\Rightarrow$ Possible band-wagon effects
Coalition Theory (4)

The size vs gain trade-off

![Graph showing the size vs gain trade-off with points labeled 1, 2, C^*_H, C^*_L, n, and the gain axis.](image)
IMPLICATIONS FOR MODELLING

- Compute incentives to join a climate coalition (or to defect from it) as a function of policies, future targets, economic and demographic scenarios, etc.

- Costs of complying with the Kyoto agreement are a function of the number of signatories … …. but signatories are a function of the costs of complying with the agreement ⇒ simultaneity
POLICY ISSUE 2: GLOBAL OR REGIONAL AGREEMENTS?

- **Theory**: many coalitions (many groups of cooperating countries) form at the equilibrium

- **Facts**: Single agreement (Kyoto Protocol) has been proposed and is presently the goal of climate negotiations

- **Still unresolved paradox**: Unless facts are interpreted differently
“In substance, even though not in form, the Kyoto Protocol reflects agreements among several different coalitions”

_Eric Haites, former head of the IPCC Technical Support Unit_

“It is increasingly becoming clear, [that] the Kyoto Protocol is less a global agreement than a set of differing regional approaches”

_Christian Egenhofer, Center for European Policy Studies_
GLOBAL OR REGIONAL AGREEMENTS?

Theoretical results:

- The equilibrium coalition structure is not formed by a single coalition. In general, many coalitions form at the equilibrium;

- Coalitions of different sizes may emerge at the equilibrium (even when countries are symmetric).

- The multiplicity of coalitions may allow for region-specific agreements in which the characteristics of countries in a given region are better reflected by the structure of the agreement that they decide to sign.
GLOBAL OR REGIONAL AGREEMENTS ?

Empirical results:

Buchner and Carraro (2002) computed economic and environmental gains when different sub-coalitions and fragmented climate regimes form.

Changes in welfare and emissions with respect to the present situation have been analysed.

Regional or fragmented agreements seem very likely, at least in terms of economic incentives.
A climate regime with two blocs: 1) US and CHN; 2) EU, FSU and Japan (per cent changes with respect to the Annex B _US coalition_)

- US
- CHN
- EU
- FSU
- JPN

<table>
<thead>
<tr>
<th>Welfare USA</th>
<th>Welfare JPN</th>
<th>Welfare EU</th>
<th>Welfare CHN</th>
<th>Welfare FSU</th>
<th>Emissions</th>
<th>R&amp;D USA</th>
<th>R&amp;D JPN</th>
<th>R&amp;D EU</th>
<th>R&amp;D CHN R&amp;D FSU</th>
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<tr>
<td>-0.30</td>
<td>-0.20</td>
<td>-0.10</td>
<td>0.00</td>
<td>0.10</td>
<td>-15%</td>
<td></td>
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### RANKING OF COALITION STRUCTURES:

<table>
<thead>
<tr>
<th></th>
<th>USA</th>
<th>JPN</th>
<th>EU</th>
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<tbody>
<tr>
<td>Rank 1</td>
<td>(JPN, EU, FSU)</td>
<td>(EU, US, FSU)</td>
<td>(JPN, US, FSU)</td>
</tr>
<tr>
<td>Rank 2</td>
<td>(JPN, CHN) &amp; (EU, FSU)</td>
<td>(JPN, CHN) &amp; (EU, FSU)</td>
<td>(USA, JPN, EU, CHN, FSU)</td>
</tr>
<tr>
<td>Rank 3</td>
<td>(JPN, EU, FSU) &amp; (USA, CHN)</td>
<td>(JPN, EU, FSU) &amp; (USA, CHN)</td>
<td>(JPN, CHN) &amp; (EU, FSU)</td>
</tr>
<tr>
<td>Rank 4</td>
<td>(JPN, EU, CHN) &amp; (USA, FSU)</td>
<td>(USA, JPN, EU, CHN, FSU)</td>
<td>(JPN, EU, FSU) &amp; (USA, CHN)</td>
</tr>
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MODELLING IMPLICATIONS

- Regionalism is an increasing phenomenon in trade. More than 200 regional trade agreements already exist.

- What about linking regional trade agreements with regional climate policy?

- What impact of regional trade rules on regional GHG emissions?

- What implications of regional emission trading schemes and of their possible subsequent linking?
SUMMING UP

• Theory suggests that partial/regional agreements are most likely to emerge at the equilibrium

• Numerical simulations suggest that a two-bloc coalition structure could form (with EU, Japan and Russia in one bloc and US and China in the second bloc).

• What about reality?
WHERE ARE WE?

- **Kyoto Protocol:**
  low environmental effectiveness, even though ratified by 122 countries (as of May 29th, 2004)
- EU and Japan have ratified the Protocol and are leading the climate coalition (that covers only 44% of total emissions)
- EU is negotiating with Russia to provide incentives for ratification (WTO deal)
AND...

- Japan focuses on domestic policies (carbon taxes) and regional cooperation (mostly with China).
- US adopted a low emission intensity target (-18%) and focuses on technology policy.
- China announced ratification, but no target.
- A number of bilateral / regional cooperations, particularly on research and technological developments, have been signed.
THE FUTURE OF KYOTO

✓ The US withdrawal from Kyoto has largely penalised Russia, that therefore delays ratification.

✓ Russia’s bargaining power has increased. Therefore, ratification can be expected only after some important economic concessions by the EU.

✓ Kyoto may not come into force, but main countries will reduce their emissions anyway.
KYOTO’S WEAKNESSES

The Kyoto Protocol’s architecture has been criticised on a variety of grounds, including:

→ it imposes high costs and unfair burdens on some industrialised countries;
→ it effectively forbids developing countries from taking on emissions commitments;
→ it provides ineffective incentives for participation;
→ and it generates modest short-term climate benefits while failing to provide a long-term solution.
PATH 2: ALTERNATIVE APPROACHES

1) A Hybrid International Trading Program with Safety Valve (Kopp, Morgenstern and Pizer, 1997; Aldy, Orszag, and Stiglitz, 2001)


3) Harmonized Domestic Carbon Taxes (Cooper, 1998, 2001)


7) A Broad but Shallow Beginning (Schmalensee, 1996, 1998)

8) A Three-Part Policy Architecture (Stavins, 2001b)

9) Emission intensity regime (Pizer, 1998)
10) Using Quotas to Attract Developing Countries (Stewart and Wiener, 2001)

11) Increasing Compliance through Buyer Liability (Victor, 2001)

12) The Global Public Good Purchase System (Bradford, 2002)

13) Regional Climate Agreements (Carraro, 1998, 2002)

14) Trade and Banking (Viguier, 2003)
"I have not failed. I’ve just found 10,000 ways that don’t work."

Thomas Alva Edison
COMMON FEATURES:

→ use of relatively moderate short-term goals;
→ use of market-based mechanisms;
→ cost constraints through hybrid instruments;
→ provision of incentives for participation and compliance.
HOWEVER:

- Kyoto target (-5.2%) is largely insufficient.
- Present post-Marrakech agreement is even weaker (-2.1%).
- More ambitious targets are too costly unless a technological breakthrough is introduced.
- Investments in research and development of new energy sources are necessary.
Carbon Intensity of Primary Energy

Global CO₂ Intensity (tC/TJ)

- SRES database scenarios
- All IIASA scenarios
- Sustainable development scenarios
MODELLING IMPLICATIONS

- Large literature on how to model technical change in climate models:
  - R&D, learning curves, knowledge spillovers, irreversibilities, path dependency …
  - Bottom-up vs. top down, endogenous vs. exogenous …
  - Etc.
MITIGATION IS NOT ENOUGH...

• Whatever action to reduce GHG emissions is taken today, climate is going to change anyway. This is true for both those who believe that human influence is small and those who believe that human influence is very important.

• Therefore, we need ADAPTATION policies.
• Adaptation implies investments to protect:
  – coastal zones and small islands (from sea level rise, ...)
  – agriculture production (from water stress, droughts ...)
  – poor countries (from loss of natural resources, ...)
  – ageing population (from heat waves and other extreme events, ...)
  – infrastructures (from floods, ...)
  – national security (migrations, political instability ..)
  – etc.
MODELLING IMPLICATIONS

• What is the optimal level of adaptation?

• Do investments in adaptation crowd out resources to be devoted to mitigation?

• Does adaptation reduce incentives to undertake mitigation?

• What is the relationship between technical change and the time profile of optimal adaptation and mitigation?

• How effective is adaptation in protecting economic systems from impacts of climate change?
• “Autonomous” vs “Planned” Adaptation
• Physical impacts of climate change can be translated into economic impacts
• A general equilibrium framework is the appropriate tool to assess how economic systems (sectors in different countries) react/adapt to impacts of climate change
• Final output is a climate induced GDP loss that take into account “autonomous” adaptation
Sea Level Rise Impacts Induced by Climate Change (Year 2050)

Gains and Losses as % of GDP

USA  EU  EEFSU  JPN  RoA1  EEex  CHIND  RoW

-0.11
-0.09
-0.07
-0.05
-0.03
-0.01

Direct Effect ■ Final Effect After Autonomous Adaptation
Health Impacts of Climate Change (Year 2050)

Gains and Losses as % of GDP

-2 -1.5 -1 -0.5 0 0.5 1

USA EU EEFSU JPN RoA1 EEx CHIND RoW

Direct effect Final Effect After Autonomous Adaptation
Climate Change Impacts On Tourism Activity (Year 2050)

Direct Effect vs Final Effect After Autonomous Adaptation
MODELLING THE ADAPTATION/MITIGATION TRADE OFF

Empirical optimal growth model with four stocks:

• Capital (cumulated via investments)
• Emissions Concentrations (cumulated via CO2 emissions)
• Defensive capital (cumulated via investment in adaptation)
• Knowledge (cumulated via R&D investments)
MODELLING THE ADAPTATION/MITIGATION TRADE OFF

And four control variables:

- capital investment
- R&D
- adaptation investment
- emission abatement
ADAPTATION/MITIGATION TRADE-OFF

% Difference in CO2 Emissions r.t. Exogenous TP No Adaptation

-15 -10 -5 0 5 10 15 20 25

1990 2000 2010 2020 2030 2040 2050 2060 2070 2080 2090 2100

% Differences:
- EXTPA
- ENTPNA
- ENTPA

Fondazione Eni Enrico Mattei
EFFECTIVENESS AND TIME PROFILE OF OPTIMAL ADAPTATION

% Difference in Discounted Environmental Damage r.t. Exogenous

TP No Adaptation

% Difference in Discounted Environmental Damage r.t. Exogenous

1990 2000 2010 2020 2030 2040 2050 2060 2070 2080 2090 2100

% EXTPA

ENTPNA

ENTPA
CROWDING-OUT EFFECTS

Endogenous TP: % Difference in The Stock of Knowledge. Adaptation - No Adaptation
OUT OF TIME?
In modern growth models, where impacts on climate change are also modelled, technical change is not only the engine of growth, but also the only way to effectively address climate change in the long-run.

Technical change has large potential in bottom-up techno-economic models. However, in long-run optimisation economic models evidence is controversial.

**New approaches** to deal with technological change in climate models. Mixed LbD and R&D models.
Past FEEM experience in modeling ETC (1)

- FEEM-RICE Model
  - An endogenously generated stock of knowledge affects both factor productivity and the emission-output ratio

- FEEM-RICE Model version 1 “Learning by Researching”
  - Knowledge is the result of the intertemporal optimal accumulation of R&D, where R&D is an additional choice variable
  - R&D spending claim on resources in addition to consumption and physical investment
Past FEEM experience in modeling ETC (2)

• FEEM-RICE Model version 2 “Learning by Doing”

  – Knowledge is approximated by installed capacity. Installed capacity is represented by physical capital, which cumulates through periodic investment.

  – LbD approach entails one less choice variable with respect to the R&D approach, but no further claim on resources.
• The absence of a Carbon Energy (CE) variable in the model.
• The impossibility of including both *Learning by Researching* and *Learning by Doing*.
• The impossibility of distinguish between R&D expenditures in the energy sector and R&D expenditures in all the other sectors.
The FEEM-RICE Model version 3

✓ Start from RICE-99 by Nordhaus and Boyer (2000), a single sector optimal growth model which accounts for the interactions between economic activities and climate.

✓ Extend the model to endogenise technical change and allow for both Learning by Researching and Learning by Doing.

✓ The new model has been developed for the eight macro regions into which the world is divided and includes Carbon Energy as a production factor.
Technical Change in FEEM RICE v.3

✓ Innovation is brought about by R&D spending which contributes to the accumulation of the stock of existing knowledge.

✓ R&D investments contribute to reduce emissions and induce a “Learning by Doing” effect, modeled as cumulated past emission abatement.

✓ These two factors are combined in an index of Technical Progress - TP - generally defined as,

\[ TP = f (Knowledge, Cumulated \_ Emissions \_ Reduction) \]
The structure of technical change in FEEM RICE v.3

R&D (t,n) → TP (t,n) → Emissions (t,n) → TP(t+1,n) → Emissions (t+1,n)

Control variable

All other model variables

Emissions (t,n) in BaU

Cumulated Emission Reductions (t,n)

State variable
Preliminary results

• Technical change more effective on energy switching than on energy saving

• Small incentives from carbon price implicit in Kyoto

• Larger incentives from ambitious future targets and from R&D protocol
THE END ?